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# Electric motors on the farm



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# Electric motors on the farm

ROGER THÉRIAULT
Research Station, Saint-Jean-sur-Richelieu, Québec

CLÉMENT VILLENEUVE
Roche Associés Ltée, Sainte-Foy, Québec

RÉGIS BOILY
Laval University, Sainte-Foy, Québec

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Les moteurs électriques à la ferme

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## 1- USE OF ELECTRIC MOTORS ON THE FARM

Today's farm is a highly mechanized, intensive production unit. Increased mechanization has promoted the use of electric motors on the farm for building ventilation; crop drying and preservation; handling of farm products, manure, and food; and operation of a broad range of tools.

An electric motor has several advantages: it can start up very large loads and withstand a temporary overload; it is far more efficient than a gasoline or diesel engine; and it is nonpolluting, quiet, and compact. Easy to operate, an electric motor can be readily equipped with automatic controls. Its useful life can be very long, with a minimum of maintenance.

The purpose of this technical bulletin is to inform the farmer about the types of motors available, their installation and maintenance, and the problems that may arise concerning their use. The bulletin was developed under research contract 10SD.01756-0-0232 by Roche Associés Ltée of Sainte-Foy, for Agriculture Canada, within the Agricultural Engineering Research and Development Program.

## 2- DESCRIPTION AND OPERATION OF ELECTRIC MOTORS

The typical electric motor used on the farm is an induction motor powered by a single-phase alternating current (120 or 240 V). Its major components are a rotor and a stator (Figure 1).

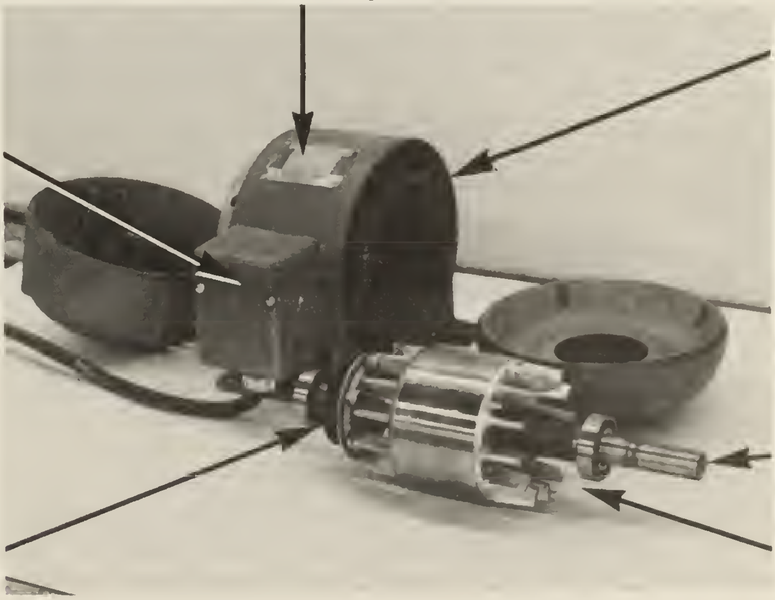



Figure 1. Exploded view of an electric motor

The rotor comprises a steel core and an aluminum squirrel cage mounted on a shaft. The stator comprises a main and auxiliary windings that create magnetic poles, the number of which determines the rotational speed of the motor (Table 1).

Table 1. Motor speed versus number of poles

| Number of poles | Motor speed (revolutions per minute) |
|---|---|
| 2 | 3450 |
| 4 | 1725 |
| 6 | 1140 |

An induction motor works like a magnet that carries along with it a metal part as it turns: the magnetic field created by the alternating current flowing in the main or run windings of the stator causes the rotor to turn. Thus, the stator transmits electric power to the rotor, which transforms it into mechanical energy.

With single-phase power, auxiliary or starting windings must be used to set up a rotating magnetic field and to start the motor; in most cases, the starting windings are disconnected by a centrifugal switch when the motor attains the normal operating speed. With three-phase power, the lag between the three phases creates a rotating field that permits effective motor starting without any starting device.

Every electric motor has a nameplate stating most of the technical specifications of that motor. Most motors also have a terminal box for connecting the motor safely to the electric circuit. Wiring diagrams for the motor windings are usually marked on the motor junction or terminal box case or on the nameplate.

## 3- MOTORS AVAILABLE ON THE MARKET

### 3.1 Motor Types

Most motors used on farm equipment are single-phase induction motors of several types that differ mainly in starting devices and consequently in starting characteristics; few three-phase type motors are used on farms. The characteristics of these motors are described herein and are summarized in Table 3 at the end of Section 3; all are single-phase induction motors except the three-phase one.

Split-phase motor. The split-phase motor (Figure 2), the simplest single-phase induction motor, has two sets of windings: auxiliary windings called starting windings and main windings. A centrifugal switch disconnects the starting windings when the motor attains 75-80% of its operating speed.

Capacitor-start, induction-run motor. The capacitor-start, induction-run motor (Figure 3) is similar to the previous one, except that it has one to three capacitors inserted in series with the starting windings, thus increasing greatly the starting torque.

Capacitor-start, capacitor-run motor. The capacitor-start, capacitor-run motor (Figure 4) has two to four capacitors connected in parallel and inserted in series in the auxiliary windings. All capacitors are used for starting and the high-value capacitors are cut off when the motor reaches 75-80% of its rated speed. The run capacitor, which has a lower capacitance, remains in series in the auxiliary windings as long as the motor is running. This motor has a good power factor because of the run-capacitor.

Permanent split-capacitor motor. The permanent split-capacitor motor (Figure 5) contains two sets of windings, but no centrifugal switch. The capacitor is used for motor starting and operation. The auxiliary windings connected in series with the capacitor are always powered during motor operation. Motor speed can be controlled by varying the supply voltage. This motor is used primarily in ventilation.

Repulsion-induction motor. The repulsion-induction motor (Figure 6) is characterized by a wound rotor commutator, brushes, and a centrifugal device. At starting, the rotor windings are connected together through brushes to form a closed loop. When the motor reaches a predetermined speed, the rotor winding is short-circuited to give the equivalent of a squirrel-cage winding. This motor starts as a repulsion motor but operates as an induction motor. Because of its high manufacturing cost, this type of motor is offered by only a few manufacturers today.

Split-phase start, capacitor-run motor. The split-phase start, capacitor-run motor is a fairly new motor comprising an auxiliary starting phase, a capacitor, and a centrifugal switch. At starting, with the capacitor disconnected, it operates like a split-phase induction motor. In operation, the capacitor is connected in series with the auxiliary winding, which provides a higher power factor and a higher efficiency. This motor runs like a permanent split-capacitor motor. It has a starting torque slightly higher than that of a conventional split-phase motor.

Three-phase motor. Three-phase induction motors are sometimes used on farms that need 7.5-kW or larger motors and where three-phase voltage is available. A three-phase motor is similar in design to a single-phase induction motor, except that it has no auxiliary starting winding, no capacitor, and no centrifugal switch. The design is simpler, and therefore the three-phase motor is more reliable and durable.

Fig.2

Fig.3

Figure 2. Split-phase motor (totally enclosed air-over motor)

Figure 3. Capacitor-start, induction-run motor (totally enclosed air-over motor)

Fig.4

Fig.5

Figure 4. Capacitor-start, capacitor-run motor (totally enclosed fan-cooled motor)

Figure 5. Permanent split-capacitor motor (totally enclosed air-over motor)

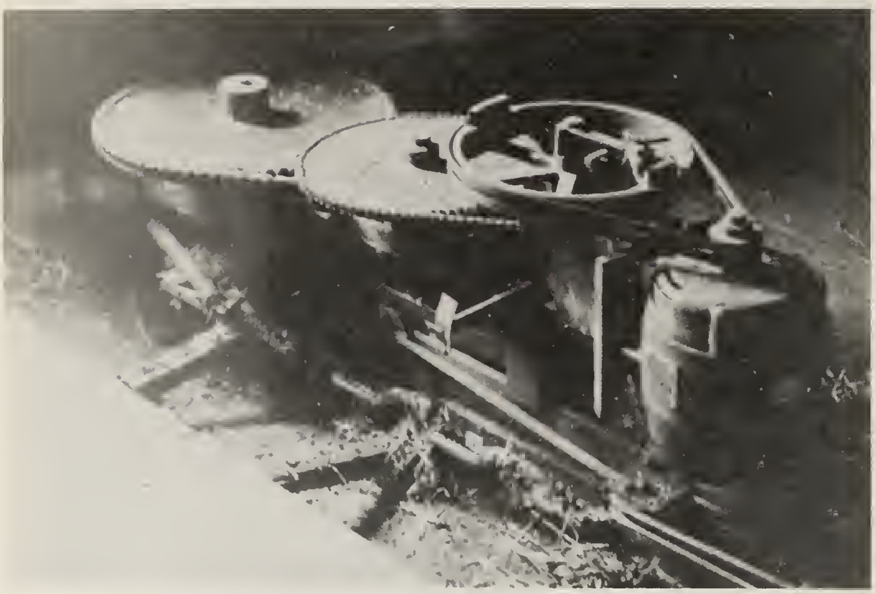


Figure 6. Repulsion-induction motor (drip-proof)

The three-phase motor has the following features. It rotates at constant speed and is designed to operate on 208 or 575 V. It is more efficient and has a power factor better than that of a single-phase motor. Its mechanical and electrical characteristics must meet the industrial rating standards of the National Electrical Manufacturers' Association (NEMA). Table 2 shows its characteristics and its farm applications.

Table 2. Characteristics and applications of the three-phase motors used on the farm

| NEMA class | Starting torque | Starting current | Typical applications |
|---|---|---|---|
| A | Normal | Normal | Centrifugal pumps, axial fans |
| B | Normal | Low | Centrifugal fans, conveyors, vacuum pumps, hydraulic pumps for liquid manure disposal, elevators |
| C | High | Low | Large grain conveyors starting under load, barn cleaners, air and cooling compressors |

## 3.2 Chassis types

Open motor. This motor is open at both ends and is cooled by the air that passes through it; the fan is fixed to the rotor. It is designed to operate in a clean environment.

Drip-proof motor. The drip-proof motor (Figure 7) is constructed so that solid or liquid particles falling vertically or near-vertically cannot enter the motor. It is cooled by the air that penetrates inside the motor; it is designed to operate in locations where there is little dust or humidity.

Totally enclosed air-over motor. The totally enclosed air-over motor is designed to prevent the penetration of dust, moisture, or other external agents. It is usually installed on fans. Air circulation around the motor frame provides cooling (see Figures 2,3, and 5).

Totally enclosed fan-cooled motor. This totally enclosed motor is cooled by an external fan operated by the motor shaft. Fully sealed, this motor can operate under moist, dirty, or dusty conditions. It is the most popular motor for use on the farm (see Figure 4).

Explosion-proof motor. The explosion-proof motor is similar to the previous one. It is designed to operate in the presence of explosive dust or gas.

Figure 7. Drip-proof motor

## 3.3 Motor Classes

General-purpose motor. General-purpose motors are built for easy operation under normal conditions in industrial and agricultural applications. These motors are suited for numerous applications around the farm and have usually the lowest investment cost.

Farm-duty motor. The farm-duty motor is a standard motor with high-quality mechanical and electrical components built for operation in a hot or damp environment. It can withstand loads that are difficult to start and tolerate frequent overloads.

The farm-duty motors are available in two types: capacitor-start, induction-run motor; and capacitor-start, capacitor-run motor. They are far more expensive than general-purpose motors.

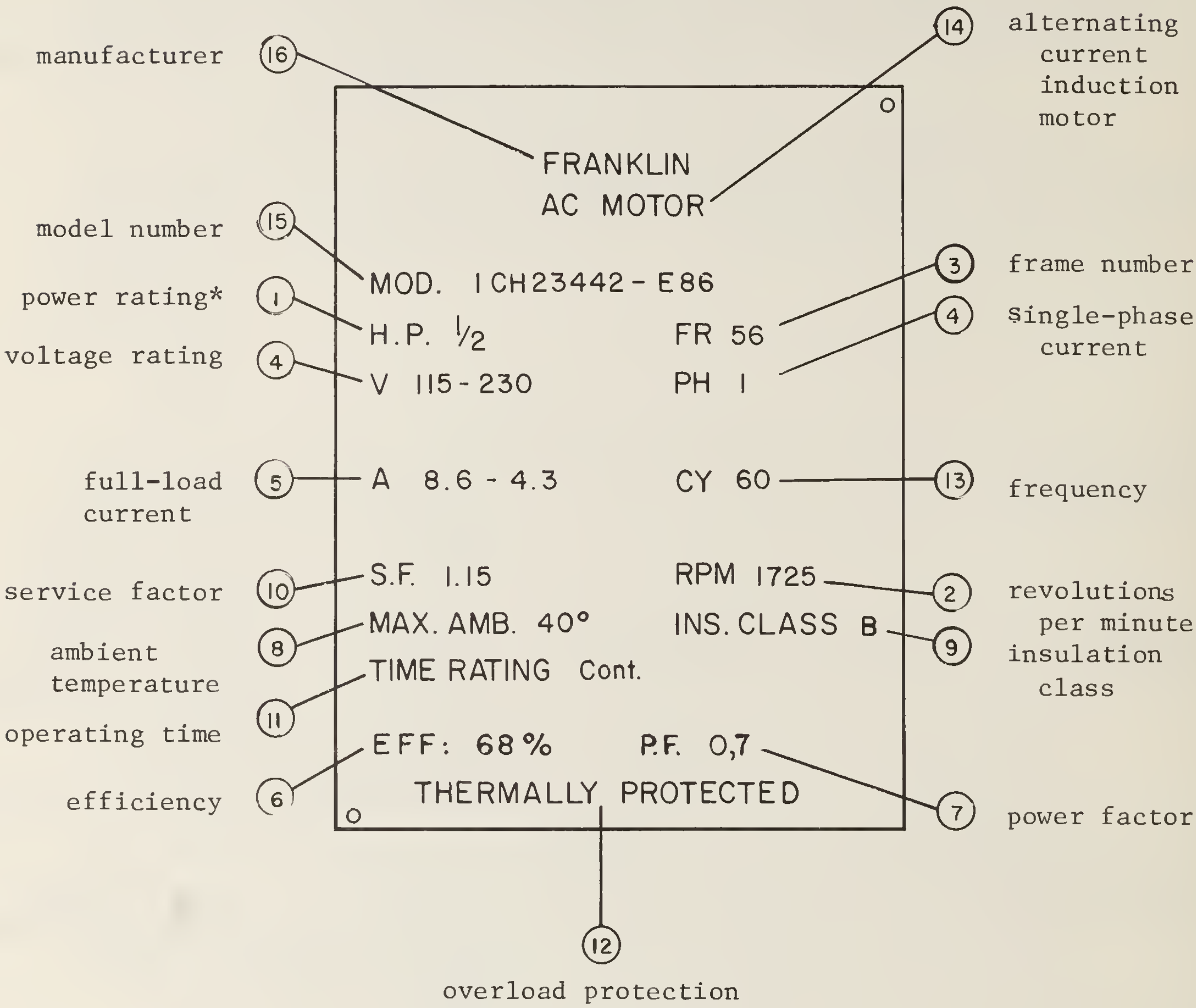
Three-phase motors are also available in different classes of service.

Table 3. Characteristics of alternating-current electric motors

| Motor type | Power range (kW) | Starting characteristics (% full load) Torque | Current | Motor characteristics | Uses |
|---|---|---|---|---|---|
| Split-phase | 0.12-0.56 | 150 | 600-700 | Low starting torque<br>Low efficiency<br>Low initial cost | Small fans<br>Centrifugal pumps<br>Small tools |
| Capacitor-start, induction-run | 0.12-3.75 | 300-400 | 300-400 | High starting torque<br>More expensive | Large fans<br>Blowers<br>Milk coolers<br>Compressors<br>Conveyors<br>Barn cleaners<br>Pumps<br>Grain |
| Capacitor-start, capacitor-run | 1.5-7.5 | 350-400 | 300-400 | High starting torque<br>Permits overloads<br>Sturdy<br>Very expensive | Hay dryers<br>Crop dryers<br>Milk coolers<br>Feed grinders<br>Compressors<br>Silo unloaders<br>Barn cleaners<br>Manure evacuators<br>Large conveyors<br>Elevators<br>Mills<br>Liquid manure pumps |
| Repulsion-induction | 0.12-7.5 | 400-500 | 450 | High starting torque<br>Permits overloads<br>Insensitive to voltage drops<br>Very expensive | |
| Split-phase start, capacitor-run | 0.12-0.56 | 150 | 600-700 | Low starting torque<br>Very efficient<br>High power factor<br>Higher initial cost | Small fans<br>Small blowers<br>Small centrifugal pumps |
| Permanent split-capacitor | 0.015-0.56 | 60 | 400-600 | Very low starting torque<br>Variable speed<br>High initial cost | Small fans<br>Small blowers |
| Three-phase | 0.37-450 | 175-300 | 250-400 | Reliable-durable<br>Very efficient<br>High power factor<br>Low initial cost | See Table 2 |

## 4- NAMEPLATE INFORMATION

The nameplate lists the mechanical and electrical specifications of the motor, in addition to some general information (Figure 8).




*½ H.P. corresponds to 0.37 kW

Figure 8. Nameplate details

The major mechanical specifications on a nameplate are:

-power rating
-rotation speed
-frame number

The power rating is the maximum continuous power developed by a motor; it should never be exceeded. The rotation speed of the motor should not drop below that specified on the nameplate, in order to avoid motor overload. Two-speed fan motors must be connected differently for low-speed operation than they are for high-speed operation. The frame number gives the standardized geometric dimensions of the motor frame and shaft diameter. The nameplate also specifies the type of frame, i.e. enclosed, open, or drip-proof, that suits the operating conditions for which the motor was designed.
The most important electrical specifications are:

-voltage rating (single-phase or three-phase)
-full-load current
-efficiency
-power factor

The voltage rating specifies the nominal supply voltage to the motor. A voltage that is too high or too low reduces the useful life of the motor and may even damage it. Dual-voltage 120/240-V motors must be connected differently for each voltage. Almost all motors used on the farm run on single-phase 120 or 240 V. For three-phase motors, the nameplate bears the marking "PH 3", which means three-phase.

The full-load current is the current drawn by the motor from the line when the motor is operating at full load. The current is lower when a dual-voltage motor operates at the higher voltage. A motor is overloaded or defective if the current drawn exceeds the full load current printed on the nameplate.

Motor efficiency measures the performance of the motor in converting the electric power used into mechanical energy when the motor is operating at full load. The efficiency of small motors rated below 0.75 kW should be between 60 and 80%, whereas that of larger motors should be 80-90%. The efficiency of a motor drops rapidly when the motor is too large for the load to be operated or when the motor is not fully loaded.

The power factor is an indication of the efficiency of the motor in actually using the electric power drawn from the power line. The ideal power factor is 1.0 and the actual factor ranges from 0.4 to 0.9 for various motors, according to the load and motor size. This factor is lower for small motors than for large motors. Farmers are often penalized by the power suppliers for a power factor below

0.9 if a separate meter measures the real power drawn from the line simultaneously with the apparent power used by the farm.

It should be noted that the efficiency and the power factor are seldom indicated on single-phase farm motors.

The remaining specifications that appear on the nameplate are:

- -ambient temperature
- -insulation class
- -service factor
- -operating time
- -overload protection (thermal device)
- -frequency: 60 Hz
- -type of current (alternating or direct)
- -model
- -manufacturer, name, address, and trademark

The specified ambient temperature is the maximum temperature of the operational environment of the motor.

The insulation class (A, B, F, or H) refers to the quality of the insulation of the wires inside the motor and determines the maximum motor operating temperature. The normal insulation class is B; for more severe load or temperature conditions, class F is preferable.

The service factor indicates that the motor can withstand a temporary overload. This factor varies between 1.0 and 1.15. A 3.73-kW motor with a service factor of 1.10 can temporarily develop a power of 4.1 kW (3.73 kW x 1.10).

The operating time indicates whether the motor can operate continuously or only intermittently.

The marking "thermally protected" shows that the motor contains an internal thermal protection device that shuts off the motor when the winding temperature becomes too high. Restarting can be automatic or manual. When automatic, the motor restarts as soon as it has cooled down. When manual, the operator must push a red button on the terminal box in order to restore power. Automatic restart cannot be used in situations where a sudden start-up could be dangerous.

The frequency rating is 60 Hz or cycles per second for alternating current; the model and serial number are specific to each motor manufacturer.

## 5- SELECTION OF ELECTRIC MOTORS

### 5.1 Criteria Governing the Selection of a Motor

Choose a replacement motor for a given purpose as follows.

- Select a motor having characteristics identical to those of the motor to be replaced
  - mechanical characteristics
    - power rating
    - rotation speed
    - frame number and type
  - electrical characteristics
    - voltage rating
    - full-load current
    - thermal protection against overload

- Ensure that the motor meets the operating and environmental requirements
  - motor class
  - insulation class
  - service factor

- Choose a motor with a high efficiency and power factor

- Match the application to a suitable motor type (consult Table 3).

## 5.2 Saving Energy and Money when Selecting a Motor

You can save energy and dollars by picking a more efficient motor. When the efficiency is not indicated, pick the motor with the lowest current rating for a particular model, class, and power rating of motor. Such a motor is usually the most efficient for a given design.

Selecting a motor with a high efficiency reduces demand, thereby lowering the energy bill for farms that are demand-metered. Permanent split-capacitor motors, capacitor-start, capacitor-run motors, and the new split-phase start, capacitor-run motors all have high power factors and are more efficient.

Table 4 shows the potential savings that can be achieved by substituting permanent split-capacitor motors for the standard split-phase motors generally used on similar fans.

Table 4. Energy costs and savings (at 3.5¢/kW.h) for ten 0.37-kW continously running motors ($)

| Period | Permanent split-capacitor motors | Split-phase motors | Saving |
|---|---|---|---|
| 1 day (24 h) | 3.91 | 5.07 | 1.16 |
| 1 week | 27.37 | 37.46 | 8.12 |
| 1 month | 117.30 | 152.10 | 34.80 |
| 1 year | 1427.15 | 1850.55 | 423.40 |

Within a few years, the energy savings pay for the additional cost of the more efficient permanent split-capacitor motors.

## 6- INSTALLATION

### 6.1 Electrical Installation

The wiring of an electric motor is very important. Proper electrical installation not only provides maximum motor efficiency for many years but also protects the motor against overloads and the operator against potential electric shocks in case of short-circuits or insulation failure.
Electric motors must always be installed by a competent electrician who is a member of the appropriate electricians' association or guild. The following recommendations are designed to help farmers understand the electrician's proposals and check whether the work has been done in accordance with the Canadian Electrical Code (Figure 9).

The following items must be checked when installing an electric motor:

- -supply voltage and motor circuit
- -conductor gauge
- -motor controls
- -motor protection
- -protection against electric shock

Supply voltage and motor circuits. Rural electric lines usually are single-phase and provide two standard voltages, 120 V and 240 V at 60 Hz. Electric motors draw electrical energy through 120 V and 240 V branch-circuits originating from the load center panel. The following general rules should be respected:

- Two or more motors below 0.25 kW may be connected to a branch-circuit or feeder provided that: a) the overcurrent devices (fuses or breakers) protecting the feeder have a rating not exceeding 15 A; b) each motor is protected by overload protective device(s).
- Motors over 0.25 kW must be connected to individual branch-circuits.
- Motors larger than 0.37 kW should be wired to operate from 240 V branch-circuits.

When using the 240-V voltage, the same amount of power is consumed as with the 120-V voltage, but the current through the conductors is reduced by half; thus it is possible to use smaller conductors with the higher voltage (see Table 5).

The utility company usually does not recommend the installation of 5.6-kW and 7.5-kW motors; farmers must consult the company and obtain its permission to use large motors because they produce high voltage drops on rural power lines, at starting.

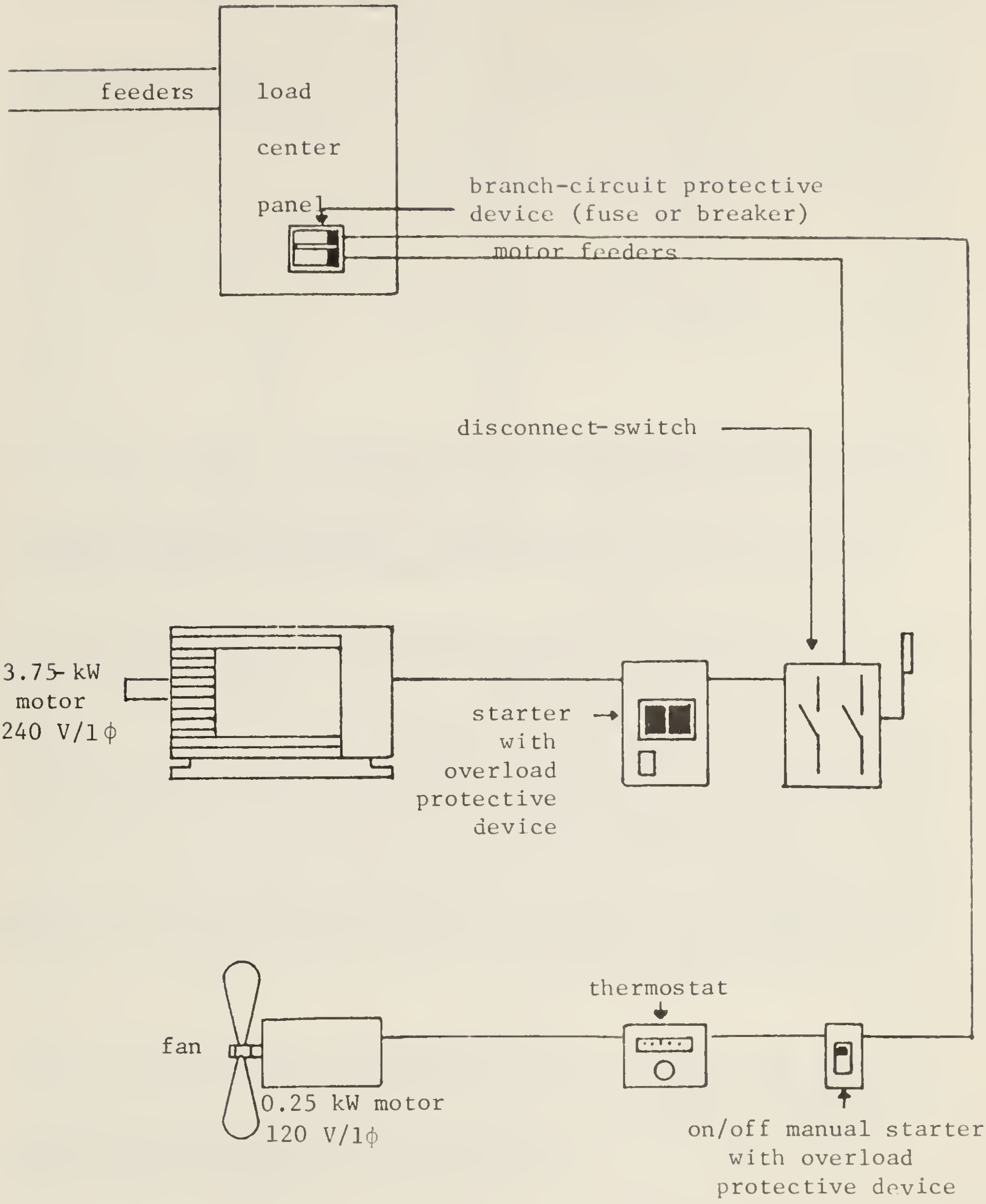



Figure 9. Motor electrical installation diagram

Table 5. Electric motor full-load current

| Power (kW) | Full-load current (A) Single-phase 115 V | 230 V | Three-phase 208 V | 575 V |
|---|---|---|---|---|
| 0.19 | 5.8 | 2.9 | | |
| 0.25 | 7.2 | 3.6 | | |
| 0.37 | 9.8 | 4.9 | 2.2 | 0.8 |
| 0.56 | 13.8 | 6.9 | 3.1 | 1.1 |
| 0.75 | 16.0 | 8.0 | 3.9 | 1.4 |
| 1.12 | | 10.0 | 5.7 | 2.1 |
| 1.49 | | 12.0 | 7.5 | 2.7 |
| 2.24 | | 17.0 | 10.5 | 3.9 |
| 3.73 | | 28.0 | 16.7 | 6.1 |
| 5.60 | | 40.0 | 24.2 | 9.0 |
| 7.46 | | 50.0 | 30.8 | 11.0 |

Source: Canadian Electrical Code (Tables 44 and 45)

1. All of these currents apply to motors with standard torque characteristics. For electrical installation, always consider the current rating indicated on the motor nameplate if this information is available.
2. Due to the high operating current of 0.37 kW to 0.75 kW, 115-V, single-phase voltage motors, it is not recommended to wire these motors for 115-V operation.

Conductor gauge. The gauge of conductors is determined by the distance between the motor and the distribution panel or load center panel, the permissible voltage drop, and the current rating of the motor. Conductor gauges are shown in Table 6.

Motor controls. In accordance with the section 28-500 of the Canadian Electrical Code, each motor must be equipped with the following starting and shutdown devices:

| Motors | Controls |
|---|---|
| - 0.25 kW and under, 115-V single-phase, portable | - Plug cap and receptacle rated at 15 A, 125 V<br>or<br>- Single-pole switch rated at 125% of full-load current, but less than 15 A, 125 V. |
| - 0.25 to 0.75 kW | - Manual starter with overload protective device, rated at 125% of motor full-load current<br>or<br>- Motor starter with start-stop push-buttons and overload protective device; rating equal to motor power rating<br>or<br>- Circuit breaker may sometimes be used. |

- 0.75 kW and over - Motor starter with start-stop push-buttons and overload protective device; rating equal to or exceeding motor power rating.

Furthermore, each motor and starter must be provided with a disconnect-switch, which must have the same power or current rating as the motor and which must be located in a position from which one can see the motor or the starter; the distance between them must be less than 9 m. In some cases, the disconnect-switch may be integrated to the starter.

Motor protection. Electric motors must be adequately protected because they often operate automatically, without supervision. The Canadian Electrical Code requires protection against overcurrents and overloads to protect the equipment, the building, and the personnel.

Overcurrent devices protect the motor and the conductors in case of short-circuits. They respond instantaneously to very high currents (6-10 times the rated current) in the event of a short-circuit or when the motor fails to start. This protection may be provided by a fuse or a circuit breaker. Without such protection, motor or conductor overheating may cause a fire.

The overload protection system protects the motor when it is drawing too much current under excessive load. It reacts slowly (1-5 min) to low currents, i.e. 125-150% of the rated current of the motor. In an overload situation, the motor draws more current. If that current is not high enough to blow the fuse or to open the circuit breaker, the overload protection then shuts down the motor and prevents motor overheating that could damage the windings or perhaps even cause fires. A 15-A circuit breaker or fuse can protect a 0.25-kW motor drawing 7.0 A at 120 V against short-circuits. If the motor is overloaded and draws 12 A, it overheats and quickly burns out without any intervention from the 15-A circuit breaker. On the other hand, an overload protection device set at 8 or 9 A opens the circuit within a few minutes and prevents destruction of the motor.

Both protections are required at all times and must meet the Code requirements. Never increase the gauge or short circuit the overcurrent and overload devices, because any overload, failure to start, or short-circuit may cause a fire or destroy the motor and the electrical equipment.

Most single-phase motors are thermally protected. This protection may be sensitive to the motor temperature or to the motor current. It is recommended at all times to provide a separate overload protection device incorporated into the motor controls, because such a device is far safer and serves to protect the complete installation.

Table 6. Minimum allowable gauge of copper conductor for 230-240 V single-phase electric motors, based on 2% voltage drop

| Full-load current of the motor (A) | Gauge | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Approximate distance to the load center panel (m) | | | | | | | | | | |
| | 12 | 18 | 24 | 30 | 37 | 43 | 49 | 55 | 61 | 73 | 85 |
| 3 | 14 | 14 | 14 | 14 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| 4 | 14 | 14 | 14 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| 5 | 14 | 14 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 10 | 10 |
| 6 | 14 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 10 | 10 | 10 |
| 7 | 12 | 12 | 12 | 12 | 12 | 12 | 10 | 10 | 10 | 10 | 10 |
| 8 | 12 | 12 | 12 | 12 | 12 | 10 | 10 | 10 | 10 | 8 | 8 |
| 10 | 12 | 12 | 12 | 12 | 10 | 10 | 10 | 8 | 8 | 8 | 8 |
| 12 | 12 | 12 | 12 | 10 | 10 | 10 | 8 | 8 | 8 | 6 | 6 |
| 14 | 12 | 12 | 10 | 10 | 8 | 8 | 8 | 8 | 6 | 6 | 6 |
| 16 | 12 | 10 | 10 | 10 | 8 | 8 | 8 | 6 | 6 | 6 | 6 |
| 20 | 10 | 10 | 10 | 8 | 8 | 6 | 6 | 6 | 6 | 4 | 4 |
| 25 | 10 | 8 | 8 | 8 | 6 | 6 | 6 | 6 | 4 | 4 | 4 |
| 30 | 8 | 8 | 8 | 6 | 6 | 6 | 4 | 4 | 4 | 4 | 3 |
| 35 | 6 | 6 | 6 | 6 | 6 | 4 | 4 | 4 | 4 | 3 | 2 |
| 40 | 6 | 6 | 6 | 6 | 4 | 4 | 4 | 4 | 3 | 2 | 2 |
| 45 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 1 |
| 50 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 2 | 2 | 1 | 1 |

Source: Agricultural Wiring Handbook (adaptation)

1. Gauges calculated for 125% of the motor current rating for thermoplastic, wet-location wires.

2. For aluminum conductors, use larger size conductors, two gauges lower.

3. For motors connected to 115 V, divide by 2 the distances given at the top of the table.

4. EXAMPLE: A 3.75-kW motor with a 30-A full-load current is installed 43 m from the load center panel. For a voltage of 230 V, the appropriate conductor gauge is No. 6.

Protection against electric shock. Motor frames and control and junction boxes must be grounded to prevent electric shock and electrocution in case of motor short-circuit and insulation failure. An electric shock is not always dangerous but it may startle the operator or cause him to fall, thus exposing him to severe equipment-caused injuries. Livestock may also be affected and even killed by ungrounded defective motors. The ground wire of the power supply cable must be firmly attached to the motor frame.

### 6.2 Mechanical Installation

Secure mounting of the motor is essential to prevent noise, vibrations, and misalignment. The motor must be mounted with its drainage ports downward. Its location must be chosen so as to prevent the accumulation of water, ice, and snow that may damage the motor.

The motor is coupled to the load either directly or by means of pulleys and belts or by gear box or chain drive. When fans are coupled directly to the motor shaft, they must be properly aligned and well balanced. When the load is driven by belts or through a gear box, the latter must be properly aligned and their tension must be adjusted for proper transmission of power and prevention of excessive bearing wear.

Most farm motors have a rotation speed of 1725 to 1740 rpm. Many types of farm equipment operate at lower speeds. The speed ratio may be adjusted by varying the diameter of the pulley or the number of teeth of the gears. V-belt is the easiest way to connect a motor to the load. The following formula is used to determine the pulley diameter that is required:

$$\text{Diameter of the equipment pulley} = \frac{\text{Motor rotation speed x Motor pulley diameter}}{\text{Equipment rotation speed}}$$

Example: What is the diameter of the pulley of a screw conveyor rotating at 435 rpm if an electric motor rotating at 1740 rpm is to be used with a 7.6-cm pulley?

$$\text{Pulley diameter} = \frac{1740 \text{ rpm x } 7.6 \text{ cm}}{435 \text{ rpm}} = 30.4 \text{ cm}$$

## 7- MAINTENANCE

When properly selected, electric motors require little maintenance; however, the following recommendations should be followed to extend the useful life of the motor and to obtain maximum efficiency.

- Keep the motor clean by removing the dust and dirt between the cooling fins or on the motor frame. With open motors, use an air blast to remove the dust that has accumulated inside.

- Check regularly that the drainage ports are not clogged or drain the motor frame by opening the drain plugs on motors that have them to eliminate condensation water.

- Check the bearing play and free rotation of the shaft. Excessive play and a sticky shaft indicate defective bearings or sleeves. Noisy bearings are a sign of failure or lack of lubrication.

- Lubricate the bearings. Check the motor manufacturer's recommendations and take the sealed bearings to a certified service center for lubrication. Lubricate all others yourself in accordance with the following recommendations:

| Type of | Lubrication period | |
|---|---|---|
| service | Lubricated bearing | Sealed bearing |
| Light | Every 2 years | Every 10 years |
| Normal | Every year | Every 7 years |
| Heavy | Every 6 months | Every 4 years |

8- COMMON PROBLEMS AND POSSIBLE REMEDIES

Motor overheating and internal corrosion are the two worst enemies of the single-phase electric motor and are at the root of most motor replacements on the farm. Farm motors are designed to operate with minimum maintenance, but this minimum level is essential. A farm survey showed that although motors were operated under severe conditions, maintenance was often neglected or nonexistent.

| Common problems | Possible causes |
|---|---|
| Motor overheats because of poor ventilation | - fan motor is dusty (Figure 10)<br>- hay conveyor motor is covered with hay and chaff<br>- dirty fan louvres cannot open (Figure 11) |
| Motor overheats because of overload | - silo unloader motor draws 50 A instead of 30 A<br>- grain fan motor is overheating because the perforated floor is obstructed or because of an excessive amount of wet grain<br>- equipment is poorly adjusted, poorly operated, or poorly maintained, as for example belts that are excessively tightened or damaged (Figure 12) |
| Motor is corroded internally | - fans shut down for the winter fail to start up in the spring because of corrosion of the centrifugal switch or seizure of the bearings |

Electrical failure occurs
- connections are loose
- contacts are corroded
- wiring is damaged
- thermostats, control boxes, or junction boxes are dirty (Figure 13), corroded, or shorted

A few remedies to minimize common problems are suggested here.

- Keep the motor clean at all times
- Avoid motor overloads
- Check tightness of anchor bolts and alignment of motor with the load
- Maintain the equipment: ensure appropriate belt tension, adjustment, and cleaning
- Periodically check the electrical connections and wires
- Keep the starter, the junction box, the thermostat, and the humidistat clean.
- To minimize internal corrosion in motors shut down for the winter, use various fans alternately during the cold months or run all of them for one day a month to flush out moisture. If a fan is too large to be started up in winter, remove its motor and store it in a dry place. Do not cover fan motors with watertight polyethylene or plastic bags, because they increase condensation.

Table 7 summarizes the main problems encountered with electric motors and suggests the possible causes and remedies for these difficulties.

Table 7. Causes and remedies for common motor problems

| Problem | Causes | Remedies |
|---|---|---|
| Motor fails to start | Blown fuse | Replace fuse |
| | Circuit-breaker opens | Reset breaker |
| | Excessive voltage drop | Check the conductor gauge<br>Check the line voltage[1] |
| | Wrong motor wiring | Check the wiring using the motor wiring diagram[1] |
| | Overload devices tripped | Check the overload protective devices in the starter<br>Check the motor thermal protection (red button on the motor)<br>Reduce the load[3] |
| | Centrifugal switch opens | Repair or replace[2] |
| | Loose connections | Check wiring connections |
| | Defective starter or motor | Repair or replace[2] |
| Motor stops suddenly | Overload | Reduce the load[3] |
| | Defective overload protective device | Replace |
| | Low voltage | Check that the voltage on the nameplate is maintained[1] |
| Motor does not reach rated speed | Wrong application or overload | Choose the correct motor type |
| | Low motor voltage | Check for proper voltage connections<br>Increase the gauge of conductor[1] |
| Motor takes too long to accelerate | Overload | Reduce the load [3] |
| | Insufficient starting torque | Install a motor with a higher starting torque |
| | Low motor voltage | Check for proper voltage connections<br>Increase the conductor gauge[1] |
| Motor vibrates and is very noisy | Poor alignment with load | Align motor and load shafts |
| | 3-phase motor operating on single phase | Check for open circuit, blown fuse, or unbalanced voltages |
| | Defective bearing | Replace<br>Check alignment |
| | Loose mounting bolts | Tighten bolts |
| | Defective coupling | Replace |
| | Unbalanced rotor or load | Rebalance rotor or load[2] |
| Motor overheats | Overload | Reduce the load[3] |
| | Belts too tight | Slacken belts |
| | Dirt prevents ventilation | Clean motor air passages |
| | Defective bearing | Clean, lubricate, or replace |
| | 3-phase motor in open circuit or unbalanced voltages | Check the connections and check for blown fuses |
| | Loose or defective connections | Clean and tighten or repair |
| | High or low voltage | Check the line voltage relative to the nameplate[1] |
| | Defective motor | Repair or replace[2] |

[1] Consult a competent electrician.

[2] Consult a certified service center.

[3] When it is impossible to reduce the load, consult the equipment dealer about installing a larger motor.

Fig.10

Fig.11

Fig.12

Fig.13

Figure 10. Dusty motor
Figure 11. Dusty fan louvres do not open
Figure 12. Worn belt
Figure 13. Dirty, fused disconnect-switch

## CONVERSION FACTORS

| Metric units | Approximate conversion factors | Results in: |
|---|---|---|
| **LINEAR** | | |
| millimetre (mm) | × 0.04 | inch |
| centimetre (cm) | × 0.39 | inch |
| metre (m) | × 3.28 | feet |
| kilometre (km) | × 0.62 | mile |
| **AREA** | | |
| square centimetre ($cm^2$) | × 0.15 | square inch |
| square metre ($m^2$) | × 1.2 | square yards |
| square kilometre ($km^2$) | × 0.39 | square mile |
| hectare (ha) | × 2.5 | acres |
| **VOLUME** | | |
| cubic centimetre ($cm^3$) | × 0.06 | cubic inch |
| cubic metre ($m^3$) | × 35.31 | cubic feet |
| cubic metre ($m^3$) | × 1.31 | cubic yards |
| **CAPACITY** | | |
| litre (L) | × 0.035 | cubic foot |
| hectolitre (hL) | × 22 | gallons |
| hectolitre (hL) | × 2.5 | bushels |
| **WEIGHT** | | |
| gram (g) | × 0.04 | oz avdp |
| kilogram (kg) | × 2.2 | lb avdp |
| tonne (t) | × 1.1 | short tons |
| **AGRICULTURAL** | | |
| litres per hectare (L/ha) | × 0.089 | gallons per acre |
| litres per hectare (L/ha) | × 0.357 | quarts per acre |
| litres per hectare (L/ha) | × 0.71 | pints per acre |
| millilitres per hectare (mL/ha) | × 0.014 | fl. oz per acre |
| tonnes per hectare (t/ha) | × 0.45 | tons per acre |
| kilograms per hectare (kg/ha) | × 0.89 | lb per acre |
| grams per hectare (g/ha) | × 0.014 | oz avdp per acre |
| plants per hectare (plants/ha) | × 0.405 | plants per acre |

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